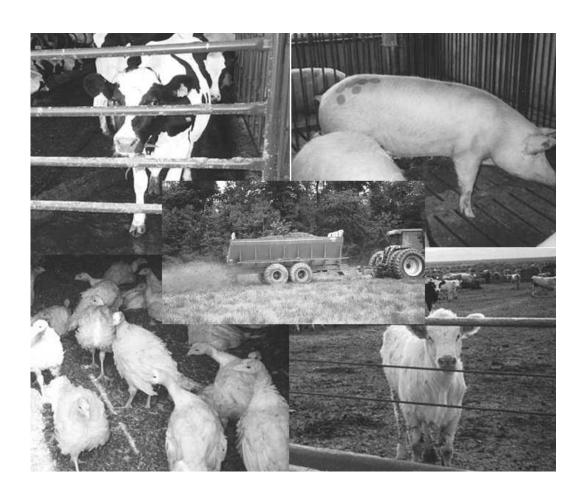


Cost Methodology for the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations

December 2002



U.S. Environmental Protection Agency Office of Water (4303T) 1200 Pennsylvania Avenue, NW Washington, DC 20460

EPA-821-R-03-004

Cost Methodology for the Final Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations

Christine Todd Whitman Administrator

G. Tracy Mehan III Assistant Administrator, Office of Water

Sheila E. Frace Director, Engineering and Analysis Division

> Paul H. Shriner Project Manager

Ronald Jordan Technical Coordinator

Engineering and Analysis Division Office of Science and Technology U.S. Environmental Protection Agency Washington, D.C. 20460

December 2002

ACKNOWLEDGMENTS AND DISCLAIMER

This report was prepared by Eastern Research Group, Inc., under the direction and review of the Office of Science and Technology.

Neither the United States government nor any of its employees, contractors, subcontractors, or other employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use of, or the results of such use of, any information, apparatus, product, or process discussed in this report, or represents that its use by such a third party would not infringe on privately owned rights.

TABLE OF CONTENTS

			Page
1.0	Intro	ODUCTION	. 1-1
	1.1	Regulatory Options	. 1-1
	1.2	Model Farm Descriptions	
		1.2.1 Beef Feedlots and Heifer Operations	. 1-8
		1.2.2 Dairies	1-10
		1.2.3 Veal Operations	1-14
		1.2.4 Swine Operations	1-15
		1.2.5 Poultry Operations	1-19
	1.3	Key Terms	1-22
		1.3.1 Size Groups	1-23
		1.3.2 Frequency Factors	1-23
		1.3.3 Manure and Waste	1-26
	1.4	Organization of Report	1-26
	1.5	References	1-27
2.0	Cost	MODEL STRUCTURE	. 2-1
	2.1	Beef and Dairy Cost Model	. 2-1
		2.1.1 Input Data to Cost Model	. 2-4
		2.1.2 Technology Calculations	. 2-5
		2.1.3 Frequency Factors	. 2-7
		2.1.4 Calculation of Weighted Costs	. 2-8
	2.2	Swine and Poultry Cost Model	2-10
		2.2.1 Input Data to Cost Model	2-13
		2.2.2 Technology Calculations	2-15
		2.2.3 Frequency Factors	2-18
		2.2.4 Calculation of Weighted Costs	2-20
	2.3	References	2-21
3.0	DATA	SOURCES	. 3-1
	3.1	Summary of EPA's Site Visit Program	. 3-1
	3.2	Industry Trade Associations	. 3-3
	3.3	U.S. Department of Agriculture (USDA)	. 3-5
		3.3.1 National Agricultural Statistics Service (NASS)	. 3-6
		3.3.2 Animal and Plant Health Inspection Service (APHIS)/National	1
		Animal Health Monitoring System (NAHMS)	3-10
		3.3.3 Natural Resources Conservation Services (NRCS)	3-13
		3.3.4 Agricultural Research Service (ARS)	
		3.3.5 Economic Research Service (ERS)	3-15
	3.4	Literature Sources	
	3.5	National Climate Data Center (NCDC)	3-16
	3.6	References	3-16

		Page
4.0	Input	DATA 4-1
	4.1	Definition of Regions
	4.2	Definition of Size Groups
	4.3	Farm Counts
		4.3.1 Farm Counts - Beef Feedlots
		4.3.2 Farm Counts - Dairies
		4.3.3 Farm Counts - Heifer Operations
		4.3.4 Farm Counts - Veal Operations
		4.3.5 Farm Counts - Poultry Operations
		4.3.6 Farm Counts - Swine Operations
	4.4	Average Head
		4.4.1 Average Head - Beef Feedlots
		4.4.2 Average Head - Dairies
		4.4.3 Average Head - Heifer Operations
		4.4.4 Average Head - Veal Operations
		4.4.5 Average Head - Poultry Operations
		4.4.6 Average Head - Swine Operations
	4.5	Wastewater/Dilution Water
		4.5.1 Wastewater Generation at Dairies 4-58
		4.5.2 Wastewater Generation at Veal Operations 4-62
		4.5.3 Wastewater and Dilution at Dry Poultry Operations 4-63
		4.5.4 Wastewater and Dilution at Swine
		and Wet Layer Operations
	4.6	Manure Generation
		4.6.1 Manure Generation at Beef Feedlots,
		Heifer Operations, Dairies, and Veal Operations 4-65
		4.6.2 Recoverable Manure Generation at Poultry Operations 4-68
		4.6.3 Recoverable Manure Generation at Swine Operations 4-70
	4.7	Precipitation Data and Runoff
		4.7.1 Precipitation Estimates
		4.7.2 Drylot Area Estimates
		4.7.3 Total Runoff
		4.7.4 Runoff Solids
	4.8	Crops and Agronomic Application Rates
	4.9	Excess Manure
		4.9.1 Beef and Dairy 4-84
		4.9.2 Poultry and Swine
	4.10	Acres 4-91
		4.10.1 Total Available Cropland Acres at Beef Feedlots,
		Dairies, Heifer and Veal Operations and Category 1
		Swine and Poultry Acreage 4-92
		4.10.2 Swine and Poultry Operations

				Page
	4.11	Refere	ences	4-107
5.0	Тесн	NOLOGY	COST EQUATIONS	5-1
	5.1		n Settling Basins	
		5.1.1	Technology Description	
		5.1.2	Design	5-2
		5.1.3	Costs	5-9
		5.1.4	Results	. 5-10
	5.2	Concre	ete Settling Basins	. 5-10
		5.2.1	Technology Description	. 5-11
		5.2.2	Design	. 5-11
		5.2.3	Costs	. 5-15
		5.2.4	Results	. 5-18
	5.3	Berms		. 5-18
		5.3.1	Technology Description	. 5-18
		5.3.2	Design	. 5-19
		5.3.3	Costs	. 5-22
		5.3.4	Results	. 5-24
	5.4	Lagoo	ns	. 5-25
		5.4.1	Technology Description	. 5-26
		5.4.2	Design of Anaerobic Lagoons	
			at Dairies and Veal Operations	. 5-27
		5.4.3	Costs for Constructing a Dairy Lagoon	. 5-39
		5.4.4	Dairy Lagoon Results	. 5-43
		5.4.5	Design of Lagoons and Evaporative Ponds for	
			Swine and Poultry Operations	. 5-43
		5.4.6	Costs for Lagoons at Swine and Poultry Operations	. 5-52
	5.5	Ponds		. 5-52
		5.5.1	Technology Description	. 5-53
		5.5.2	Design	. 5-54
		5.5.3	Costs	. 5-63
		5.5.4	Results	. 5-67
	5.6	Nutrie	nt Management	. 5-67
		5.6.1	Nutrient Management Plan Development	
			and Associated Costs	. 5-67
		5.6.2	Soil Sampling	. 5-68
		5.6.3	Manure Sampling	. 5-69
		5.6.4	Recordkeeping and Reporting	. 5-70
		5.6.5	Commercial Nitrogen Fertilizer	. 5-71
		5.6.6	Lagoon Depth Marker	. 5-71
		5.6.7	Establishment of Setback Areas	. 5-72
		5.6.8	Manure Spreader Calibration	. 5-73

		Page
5.7	Screen Solid-Liquid Separation for Swine Operations	5-74
	5.7.1 Technology Description and Design	
	5.7.2 Costs	
5.8	Land Application	
	5.8.1 Center Pivot Irrigation	
	5.8.2 Traveling Gun Irrigation	
	5.8.3 Beef and Dairy Irrigation Costs	
5.9	Transportation	
	5.9.1 Technology Description	
	5.9.2 Design and Costs of Contract Hauling	
	5.9.3 Design and Cost of Purchase Equipment	
	Transportation Option	5-89
	5.9.4 Transportation Cost Test	
	5.9.5 Results	
5.10	Ground-Water Assessment and Monitoring	
	5.10.1 Technology Description	
	5.10.2 Design and Costs	
	5.10.3 Results	
5.11	Concrete Pads	. 5-100
	5.11.1 Description of Concrete Pads	
	5.11.2 Design	. 5-101
	5.11.3 Costs	. 5-107
	5.11.4 Results	. 5-109
5.12	Composting	. 5-109
	5.12.1 Technology Description	
	5.12.2 Design	. 5-111
	5.12.3 Costs	. 5-116
	5.12.4 Results	. 5-119
5.13	Anaerobic Digestion with Energy Recovery	. 5-119
	5.13.1 Technology Description	. 5-120
	5.13.2 Design	. 5-122
	5.13.3 Costs	. 5-124
	5.13.4 Results	. 5-127
5.14	Litter Storage Sheds	. 5-127
5.15	Lagoon Covers	. 5-129
5.16	Feeding Strategies	. 5-132
	5.16.1 Technology Description	. 5-132
	5.16.2 Costs	
5.17	Options to Retrofit Swine and Wet Layer Systems	
	to Dry Systems	. 5-139
	5.17.1 Lagoon Cleanout and Closure Costs	. 5-140
	5.17.2 Retrofit to Scraper System	. 5-141

			Page
		5.17.3 Retrofit to High Rise Hog Houses	5-144
		5.17.4 Retrofit to Hoop Houses	5-145
	5.18	Recycling of Flush Water	5-146
	5.19	Sludge Cleanout	
		5.19.1 Technology Description	
	5.20	Surface Water Monitoring	
		5.20.1 Practice Description	
		5.20.2 Prevalence of the Practice in the Industry	
		5.20.3 Design	
		5.20.4 Costs	
		5.20.5 Results	
	5.21	References	5-153
6.0	FREQ	UENCY FACTORS	6-1
	6.1	Beef and Dairy Technology Frequency Factors	. 6-2
		6.1.1 Performance-Based Frequency Factors	
		Based on USDA Data	
		6.1.2 Other Performance-Based Frequency Factors	
		6.1.3 Other Technology Frequency Factors	
	6.2	Beef and Dairy Nutrient Basis Frequency Factors	
	6.3	Beef and Dairy Land Availability Frequency Factors	
	6.4	Poultry and Swine Technology Frequency Factors	
	6.5	Poultry and Swine Nutrient Basis Frequency Factors	
	6.6	Poultry and Swine Land Availability Frequency Factors	
	6.7	Ground Water Control Frequency Factors	
	6.8	References	6-45
7.0	EXAM	MPLE MODEL CALCULATIONS	7-1
	7.1	Beef and Dairy Model Farm Example Calculation	7-1
		7.1.1 Unit Component Costs	7-2
		7.1.2 Calculation of Weighted Component Costs	
		7.1.3 Calculation of Weighted Farm Costs	. 7-7
		7.1.4 Final Model Farm Costs	7-11
	7.2	Swine and Poultry Model Farm Cost Example	7-12
		7.2.1 Unit Component Costs	
		7.2.2 Calculation of Adjusted Component Costs	7-20
		7.2.3 Calculation of Weighted Farm Costs	
		by Nutrient Application Basis for Option 2	. 7-27
		7.2.4 Final Model Farm Costs	. 7-28
8.0	SENSI	ITIVITY ANALYSES	8-1
	8.1	Option 1A	. 8-2

			Page
	8.2	Cost Driver Analysis	. 8-3
	8.3	Option 2A	. 8-4
	8.4	Option 2B	. 8-5
	8.5	Applications to Frozen Ground	. 8-6
	8.6	References	. 8-9
		LIST OF APPENDICES	
A	Unwe	eighted Component Costs	
В		ted Transportation Option for Options 1 and 2 for Beef Feedlots, Dairies or Operations	s, and
C	Mode	el Farm Costs for Options 1, 2 and 5	

LIST OF TABLES

	Page
1.1-1	Summary of Regulatory Options
1.2.4-1	Model Swine Farms by Farm Type, Size, Region, and Waste Storage System
1.2.5-1	Model Poultry Farms by Farm Type, Size, and Region
1.3-1	Size Classes for Model Farms
2.1-1	Beef and Dairy Model Farm Records
2.1.2-1	Waste Management Technologies for Beef Feedlots, Dairies, and Heifer and Veal Operations
2.2.1-1	Swine and Poultry Model Farm Input Records
3-1	Number of Site Visits Conducted by EPA for the Various Animal Industry Sectors
4.1-1	Animal Feeding Operation (AFO) Production Regions 4-2
4.1-2	Key Regions Modeled by Animal Sector
4.2-1	Size Classes for Model Farms ^a
4.3.1-1	Number of Potential Beef CAFOs by EPA Size Class From the 1997 Census of Agriculture Database
4.3.1-2	Percentage of Beef Feedlots by Region and Census of Agriculture Size Category
4.3.1-3	Number of Beef Feedlots by Region and Size Class
4.3.1-4	Percentage of Beef Facilities That Are Expected to Be CAFOs 4-9
4.3.2-1	Number of Potential Dairy CAFOs by EPA Size Class from the 1997 Census of Agriculture Database
4.3.2-2	Percentage of Dairies by Region and Census of Agriculture Size Category
4.3.2-3	Number of Dairies by Region and Size Class

		Page
4.3.2-4	Percentage of Dairies That Are Expected to Be CAFOs	4-11
4.3.3-1	Number of Potential Heifer CAFOs by EPA Size Class from the 1997 Census of Agriculture Database	4-12
4.3.3-2	Percentage of Heifer Operations by Region and Size Class	4-13
4.3.3-3	Number of Heifer Operations by Region and Size Class	4-14
4.3.3-4	Percentage of Heifer Operations That Are Expected to Be CAFOs	4-14
4.3.4-1	Number of Potential Veal CAFOs by EPA Size Class from the 1997 Census of Agriculture Database	4-15
4.3.4-2	Percentage of Veal Operations by Region and Size Class	4-15
4.3.4-3	Number of Veal Operations by Region and Size Class	4-16
4.3.4-4	Percentage of Veal Operations That Are Expected to Be CAFOs	4-16
4.3.5-1	Number of Layer Operations by EPA Size Class from the 1997 Census of Agriculture Database	4-17
4.3.5-2	Number of Layer Operations by Size Class and Region from 1997 Census of Agriculture Database	4-18
4.3.5-3	Reorganized Layer and Pullet Operation Counts	4-18
4.3.5-4	Reorganized Distribution of Dry Layer, Wet Layer, and Pullet Operations by Region	4-19
4.3.5-5	Reorganized Distribution of Dry Layer, Wet Layer, and Pullet Operations	4-20
4.3.5-6	Intermediate Layer Operation Counts by Sector, Size Class, and Region	4-22
4.3.5-7	Final Layer Operation Counts by Sector, Size Class, and Region	4-23
4.3.5-8	Final Layer Operation Counts by Sector, Size Class,	

	Pag	e
	and Modeled Region	4
4.3.5-9	Percentage of Layer Operations That Are Expected to Be CAFOs	4
4.3.5-10	Percentage of Dry Layer Operations That Are Expected to Be CAFOs	5
4.3.5-11	Number of Turkey Operations by Size Class from 1997 Census of Agriculture Database	5
4.3.5-12	Number of Turkey Operations by Size Class and Region from 1997 Census of Agriculture Database	6
4.3.5-13	Reorganized Turkey Operation Counts	7
4.3.5-14	Final Turkey Operation Counts by Size Class and Region 4-2	7
4.3.5-15	Final Turkey Operation Counts by Size Class and Modeled Region	8
4.3.5-16	Percentage of Turkey Operations That Are Expected to Be CAFOs	8
4.3.5-17	Number of Broiler Operations as Provided by USDA NRCS (2002) Based on Analyses of 1997 Census of Agriculture Database	9
4.3.5-18	Intermediate Number of Broiler Operations Based on Location, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	2
4.3.5-19	Intermediate Number of Broiler Operations Based on Location, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	3
4.3.5-20	Final Number of Broiler Operations Based on Region, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure 4-3-4-3-4-3-4-3-4-3-4-3-4-3-4-3-4-3-4-3	
4.3.5-21	Final Number of Broiler Operations Based on Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure 4-3:	
4.3.5-22	Final Number of Broiler Operations Based on Modeled Region,	

		Page
	Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-36
4.3.5-23	Final Number of Broiler Operations Based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	4-36
4.3.5-24	Percentage of Broiler Operations That Are Expected to Be CAFOs	4-37
4.3.6-1	Number of Swine Operations as Provided by USDA NRCS (2002) Based on Analyses of 1997 Census of Agriculture Database	4-39
4.3.6-2	Intermediate Number of Swine Operations Based on Location, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-40
4.3.6-3	Intermediate Number of Swine Operations Based on Location, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	4-41
4.3.6-4	Final Number of Swine Operations Based on Region, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-42
4.3.6-5	Final Number of Swine Operations Based on Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure .	4-43
4.3.6-6	Final Number of Swine Operations Based on Modeled Region, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-44
4.3.6-7	Final Number of Swine Operations Based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	4-44
4.3.6-8	Percentage of Swine Operations That Are Expected to Be CAFOs	4-45
4.4.1-1	Number of Fattened Cattle at Potential CAFOs by EPA Size Class from the 1997 Census of Agriculture Database	4-46
4.4.2-1	Number of Dairy Cows at Potential CAFOs by EPA Size Class from the 1997 Census of Agriculture Database	4-48

		Page
4.4.3-1	Average Head for Heifer Model Farm	4-49
4.4.4-1	Average Head for Veal Model Farm	4-50
4.4.5-1	Layer Facility Demographics from the 1997 Census of Agriculture Database	4-51
4.4.5-2	Average Head Count for Layer Operations	4-52
4.4.5-3	Turkey Facility Demographics from the 1997 Census of Agriculture Database	4-53
4.4.5-4	Final Number of Broilers per Operation Based on Modeled Region, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-54
4.4.5-5	Final Number of Broilers per Operation Based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	4-55
4.4.6-1	Final Number of Swine per Operation Based on Modeled Region, Land Availability Category, Operation Size for Nitrogen-Based Application of Manure	4-56
4.4.6-2	Final Number of Swine per Operation Based on Modeled Region, Land Availability Category, Operation Size for Phosphorus-Based Application of Manure	4-57
4.5.1-1	Milk Parlor Wastewater Generated at Dairies Using Hose Systems	4-58
4.5.1-2	Milk Parlor Wastewater Generated at Dairies Using Flush Systems	4-60
4.5.1-3	Wastewater Generation by Dairy Model Farm	4-62
4.5.2-1	Wastewater Generation by Veal Model Farm	4-63
4.6.1-1	Cattle Manure Production and Characteristics	4-66
4.6.1-2	Cattle Manure Generation by Model Farm	4-67
4.6.2-1	Poultry Manure Characteristics Used to Calculate Nutrient Production	4-68

		Page
4.6.2-2	Poultry Regional Recovery Factors for Manure	4-69
4.6.2-3	Example of Weighted Averaging Method for Manure Recovery Factor	4-69
4.6.3-1	Swine Manure Characteristics Used to Calculate Nutrient Production	4-71
4.6.3-2	Swine Regional Recovery Factors for Manure	4-71
4.7.1-1	Precipitation Estimates	4-74
4.7.2-1	Drylot Area Required by Animal Type ^a	4-74
4.7.2-2	Drylot Area Required by Animal Type Used in the Cost Model	4-75
4.7.3-1	Six-Month Runoff Volumes	4-76
4.7.3-2	25-Year, 24-Hour Rainfall Event Runoff Values	4-77
4.7.3-3	10-Year, 10-Day Rainfall Event Runoff Values	4-78
4.8-1	Beef and Dairy Crop Information	4-81
4.8-2	Total Crop Nutrient Requirements and Manure Application Rates	4-83
4.9.1-1	USDA Data on Manure Production at Livestock Facilities	4-85
4.9.1-2	Excess Manure Estimates by Animal Type and Size Class	4-86
4.9.2-1	On-Farm Acreage for Category 2 Layer and Turkey Operations	4-89
4.9.2-2	On-Farm Acreage with Manure Applied for Category 2 Broiler Operations	4-90
4.9.2-3	On-Farm Acreage with Manure Applied for Category 2 Swine Operations	4-91
4.10.1-1	Category 1 and 2 Total Acreages for Beef Feedlots, Dairies, Heifer and Veal Operations Option 2	4-95
4.10.1-2	Evapotranspiration Rate	4-99

	Pa	age
4.10.1-3	1996 Average Regional Precipitation	99
4.10.1-4	Regional Soil Permeability	100
4.10.1-5	Days of Irrigation	101
4.10.1-6	Maximum Design Hydraulic Loading Rate Based on Annual Permeability Evaluation	102
4.10.1-7	Minimum Number of Acres Required to Apply All Liquid at the Hydraulic Loading Rate Under Option 2	104
5.1.2-1	Design Parameters for Earthen Basins	5-4
5.1.2-2	Earthen Basin Volume by Model Farm for All Regulatory Options	5-6
5.1.3-1	Unit Costs for Earthen Basins	5-9
5.2.2-1	Concrete Basin Volume by Model Farm for All Regulatory Options 5	-14
5.2.3-1	Unit Costs for Concrete Settling Basin	-15
5.3.2-1	Space Requirements Assumed for Animals Housed on Drylots 5	-20
5.3.2-2	Berm Perimeter by Beef and Dairy Model Farm for All Regulatory Options	5-21
5.3.3-1	Unit Costs for Constructing Berms	-23
5.4.2-1	Lagoon Storage Capacities at Dairies for Option 7 5	-36
5.4.3-1	Unit Costs for Storage Lagoon	-40
5.4.5-1	Chronic Rainfall Amounts for Option 1A for Swine and Poultry 5	-45
5.4.5-2	Relationships Among Depth, Side Slope, Volume, And Bottom Width of Lagoons	i-48
5.4.5-3	Depth and Side Slopes for Lagoons and Evaporative Ponds 5	-49

		Page
5.5.2-1	Pond Storage Capacities at Beef Feedlot and Heifer Operations for Option 7	. 5-57
5.5.3-1	Unit Costs for Storage Pond	. 5-64
5.6.5-1	Retail Cost of Nitrogen Fertilizer	. 5-71
5.8.3-1	Costs for Data Points from Center Pivot Irrigation Cost Curves	. 5-81
5.8.3-2	Costs for 250-gpm Liquid Applicators	. 5-82
5.9.2-1	Hauling Distances for Transportation	. 5-87
5.9.2-2	Rates for Contract Hauling for Category 2 and 3 Beef Feedlots and Dairies	. 5-88
5.9.2-3	Hauling Rates for Category 2 and 3 Swine and Poultry Operations	. 5-88
5.11.3-1	Unit Costs for Concrete Pad	5-108
5.12.3-1	Unit Costs for Composting	5-117
5.13.2-1	FarmWare Input Table	5-123
5.13.2-2	FarmWare Design Information	5-124
5.13.3-1	Digester Costs for Swine	5-127
5.15-1	Manufacturer-Suggested Costs of Lagoon Covers for ½-Acre Lagoons	5-131
5.16.2-1	Feeding Strategy Costs for Swine and Poultry	5-134
5.16.2-2	Crop Nutrient Uptake	5-136
5.20-1	Number of Samples	5-152
5.20-2	Capital Costs for Surface Water Sampling	5-152
5.20-3	Annual Costs for Surface Water Sampling	5-153
6.1.1-1	Correlation of EPA Beef Model Farm Components and USDA Representative Farm Components	6-7

		Page
6.1.1-2	Correlation of EPA Dairy Model Farm Components and USDA Representative Farm Components	6-8
6.1.1-3	Percentage of EPA Beef Feedlots and Heifer Operations in USDA Regions	6-9
6.1.1-4	Percentage of EPA Dairies in USDA Regions	6-10
6.1.1-5	Percentage of Beef Feedlots and Heifer Operations Incurring Earthen Basin Costs for All Regulatory Options	6-11
6.1.1-6	Beef Feedlots, Heifer Operations, and Dairies Incurring Costs to Install and Maintain Berms for All Regulatory Options	6-12
6.1.1-7	Beef Feedlots, Heifer Operations, and Dairies Incurring Costs for Liquid Land Application for All Regulatory Options	6-13
6.1.1-8	Beef Feedlots, Heifer Operations, and Dairies Incurring Costs for Nutrient Management Planning for All Regulatory Options	6-14
6.1.2-1	Frequency Factors Identified from Literature and Used to Calculate Low, Medium, and High Frequency Factors for Beef and Dairy Cost Model	6-16
6.1.3-1	Percentage of Beef Feedlots, Heifer Operations, Dairies, and Veal Operations Incurring Costs to Install a Naturally Lined Pond or Lagoon	6-18
6.1.3-2	Percentage of Category 2 Beef Feedlots, Heifer Operations, and Dairies Incurring Costs for Transporting Excess Manure and Waste Off Site	6-19
6.2-1	Percentage of Nitrogen-Based and Phosphorus-Based Application Facilities	6-22
6.3-1	Percentage of Category 1, 2, and 3 Facilities Using Nitrogen- and Phosphorus-Based Applications	6-24
6.4-1	Illustration of Method to Calculate Frequency Factors from Weighted Averages	6-27

		Page
6.4-2	Broiler Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities By Region That Already Incur Costs	6-29
6.4-3	Turkey Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-30
6.4-4	Layer Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-31
6.4-5	Swine Farrow-to-Finish Operations (Lagoon and Evaporative Lagoon) Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-32
6.4-6	Swine Farrow-to-Finish Operations (Deep Pits) Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-33
6.4-7	Swine Grow/Finish Operations (Lagoon and Evaporative Lagoon) Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-34
6.4-8	Swine Grow/Finish Operations (Deep Pits) Frequency Factors: Percent of High (H), Medium (M), Low (L) Performance Facilities That Already Incur Costs	6-35
6.5-1	AFO Nutrient Management Planning Basis by Animal Sector and Region Based on Percentage of Agricultural Soils Analyzed by Soil Test Laboratories in 1997 That Tested High or Above for Phosphorus	6-40
6.6-1	Percentage of Category 1, 2, and 3 Operations for Layers and Turkeys	6-41
6.2-1	Percentage of Facilities Incurring Ground Water Costs Under Option 3A/3B	6-42
6.2-2	Percentage of Beef Feedlots, Dairies, and Heifer Operations Incurring Ground Water Costs Under Option 3C/3D	6-44
7.1.1-1	Component Costs for Option 2 That Do Not Vary by Nutrient Application Basis Flush Dairy, Large 1, Central	. 7-3
7.1.1-2	Component Costs for Option 2 That Vary by Nutrient Application Basis Flush Dairy, Large 1, Central	. 7-4

		Page
7.1.1-3	Transportation Costs for Option 2 Flush Dairy, Large 1, Central	7-5
7.1.2-1	Percentage of Operations Assumed to Have Equivalent Technology In Place Flush Dairy, Large 1, Central	7-6
7.1.2-2	Weighted Component Costs for Option 2 That Do Not Vary by Nutrient Application Basis and Land Availability Category Medium Performance, Flush Dairy, Large 1, Central	7-7
7.1.3-1	Weighted Component Costs for Option 2 That Vary by Nutrient Application Basis and Land Availability Category Medium Performance, Flush Dairy, Large 1, Central	7-8
7.1.3-2	Land Availability Category Frequency Factors Dairies, Large 1	7-9
7.1.3-3	Weighted Farm Costs for Option 2 Medium Performance, Flush Dairy, Large 1, Central	7-11
7.1.4-1	Model Farm Costs by Category Medium Performance, Flush Dairy, Large 1, Central	7-12
7.2-1	Component Costs for That Do Not Vary by Option, Facility Category, or Manure Nutrient Application Basis Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-15
7.2-2	Component Costs for Facilities that Land Apply Manure On-Site Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-15
7.2-3	Component Costs for That Do Not Vary by Facility Based on Head Count Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-16
7.2-4	Component Costs for Options 1 and 2 That Vary by Facility Based on Acreage (Category 1 and 2 only) Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-17
7.2-5	Component Costs That Are Unique to Category 2 Facilities Options 1 and 2 Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-19
7.2-6	Percent Operations Assumed to Have Equivalent Technology In Place Swine Grow-Finish Operations with Lagoons, Large 1, Mid-Atlantic Region	7-21

		Page
7.2-7	Adjusted Component Costs That Do Not Vary by Option, Facility Category, or Manure Nutrient Application Basis Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-22
7.2-8	Adjusted Component Costs for Option 2 That Do Not Vary for Facilities That Land Apply Manure On Site Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-23
7.2-9	Adjusted Component Costs That Vary by Facility Based on Head Count Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-24
7.2-10	Adjusted Component Costs by Performance Level for Options 1 and 2 That Vary by Facility Based on Acreage (Category 1 and 2 only) Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-25
7.2-11	Adjusted Component Costs That are Unique to Category 2 Facilities Options 1 and 2, Swine Grow-Finish with Lagoons, Large 1, Mid-Atlantic	7-26
7.2-12	Assumed Nutrient Land Application Frequency For Total Facilities For Key Swine Regions Under Option 2	7-27
7.2-13	Final Weighted Costs for Large 1 Grow-Finish Swine Operations With Lagoons in the Mid-Atlantic Region Under Options 1 and 2	7-29
8.2-1	Results of Cost Driver Analysis	. 8-4

LIST OF FIGURES

		Page
1.1-1	Animal Feeding Operation (AFO) Production Regions	. 1-7
1.2.1-1	Beef and Heifer Model Farm Waste Management System	1-10
1.2.2-1	Dairy Model Farm Waste Management Systems	1-13
1.2.3-1	Veal Model Farm Waste Management System	1-15
1.2.4-1	Swine Model Farm Waste Management System	1-17
1.2.5-1	Poultry Model Farm Waste Management System	1-21
2.1-1	Flow Chart of General Cost Methodology	. 2-2
2.1.2-1	Components of Technology Cost Modules	. 2-6
2.2-1	Flow Chart of Swine and Poultry Cost Model	2-12
2.2.2-1	Practices Included Under Option 2A, Phosphorus-Based Management	2-19
5.1.2-1	Cross-Section of an Earthen Basin	. 5-3
5.1.2-2	Sloped Sides of Earthen Basin	. 5-8
5.2.2-1	Concrete Settling Design	5-13
5.3.2-1	Cross-Section of Berm	5-19
5.4.2-1	Cross-Section of an Anaerobic Lagoon	5-29
5.4.2-2	Volatile Solids Loading Rate (Source: USDA, 1996)	5-32
5.4.5-1	Frustrum	5-45
5.5.2-1	Cross-Section of a Storage Pond	5-55
5.8.1-1	Schematic of Center Pivot Irrigation System	5-78
5.10.2-1	Schematic of Ground-Water Monitoring Wells	5-97
5.11.2-1	Concrete Pad Design	5-103

LIST OF FIGURES (Continued)

		Page
5.12.2-1	Windrow Composting	5-113
5.17.2-1	Scraper System	5-143